UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 333

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 16, 1916

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TERMITES, OR "WHITE ANTS," IN THE UNITED STATES: THEIR DAMAGE, AND METHODS OF PREVENTION

By

THOMAS E. SNYDER, M. F., Assistant in Forest Entomology,
Forest Insect Investigations

CONTENTS

	Page		Page
Introduction	1	The Swarm	8
Classification	1	Geographical Distribution	12
Description of the Insects	2	Economic Importance of Termites in the United States	13
Communal Organization and Life	4	Preventive and Remedial Measures	26
The Life Cycle	5		

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	Page.		Page.
Introduction	1	The swarm	8
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INTRODUCTION.

Termites, or "white ants," which are classed among the most injurious insects to man's industry in tropical regions, are by no means restricted to the Tropics and in the United States are capable of seriously damaging the woodwork as well as the contents of buildings and other structures of wood, and occasionally the roots of living trees and various growing crops. In the United States these insects more frequently occur and more often become a pest in the Southern States. Due to their subterranean habits, insidious method of attack, and often countless numbers, termites are very difficult to destroy. Always coming up through underground galleries, they work under cover, avoiding exposure to the light, so that the damage is often hidden until beyond repair.

CLASSIFICATION.

"White ants" are not ants, but, because of their superficial resemblance to ants (except in color) and their communal habits, they have been almost universally so termed. Thus these insects, since they live

[1] The species principally treated herein are *Leucotermes flavipes* Kollar, *L. virginicus* Banks, and *L. lucifugus* Rossi.

in colonies which are made up of various highly specialized forms or castes, are naturally to be classed among the so-called social insects, comprising the ants, bees, and wasps. Each of these forms has a duty in this organization and there is a division of labor. In the systematic classification of insects, however, termites are widely separated from the other social insects, which represent the highest and most specialized development, while termites are among the lowest and oldest insects. Further, in many points in their life habits termites differ widely from the other social insects.

DESCRIPTION OF THE INSECTS.

THE DIFFERENT FORMS OR CASTES IN THE COLONY.

Since the work of termites is largely subterranean, or under cover, the insects are rarely observed at work and the injury is often hidden

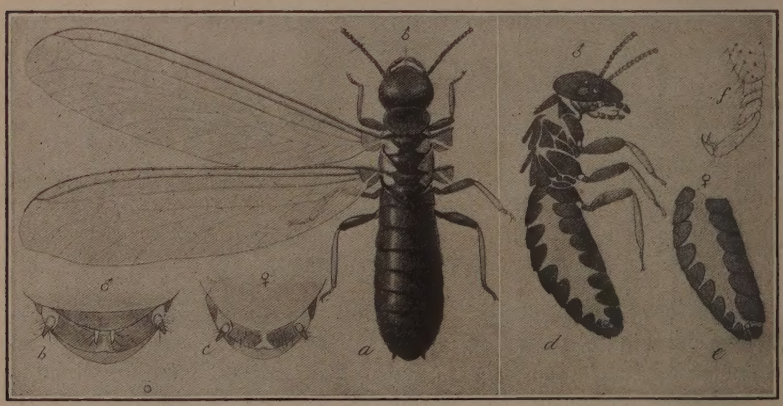


FIG. 1.—*Leucotermes flavipes: a*, Adult male; *b*, terminal abdominal segments from below; *c*, same of female; *d*, male, side view, somewhat inflated by treatment with ammonia; *e*, abdomen of female, side view; *f*, tarsus, showing joints and claws. *a*, *d*, *e*, Enlarged; *b*, *c*, *f*, greatly enlarged. (After Marlatt.)

until the destruction of the wood that they are inhabiting is complete. An indication of the presence of termites is the annual flight or swarm of the winged colonizing sexed adults which emerge in enormous numbers from the ground and crevices or holes in infested wood.

In the communal societies of termites, however, there are both wingless and winged mature individuals, as well as the young of the different forms in various stages of development. The brownish or blackish, elongate, slender, antlike adults (fig. 1) with long white wings are not the most destructive form, although they have biting mouthparts, but are migratory individuals which have the sexual organs developed, and appear normally only once a year during a certain season, which varies with the species. These male and female

reproductive forms have functional eyes, and, unlike the other forms, are especially adapted to endure full sunlight, since it is necessary that they come above ground to found new colonies, possibly because of a superabundance of life in the old, parent colony, or in order that the species may become more widely disseminated.

The dirty-white, soft-bodied, large-headed, wingless "workers" (Pl. I, fig. 1) comprise the most destructive form. These "workers" have varied and important duties; they make the excavations, enlarge and extend the colony as this becomes necessary, and care for and protect the young and reproductive forms. The soft-bodied, wingless "soldiers" (Pl. I, fig. 2), which have an elongate narrow head armed with long, slender, saber-shaped jaws, and the workers are the most numerous forms permanently present in the colony. The duty of the specially developed soldiers is apparently protective. Both the workers and soldiers consist of individuals of either sex, but the sexual organs remain undeveloped. The integument of the body of these insects is delicate and the chitinous plates are never very hard. These forms are blind and rarely appear above ground; hence in all their operations they carefully shun the light, which they nevertheless are apparently able to detect. Other forms are the reproductive individuals, which may be either a single pair, the normal king and queen (Pl. II, figs. 1 and 2), or in other colonies many supplementary forms of nymphal types (Pl. II, figs. 3 and 4; text fig. 4, *b*) or larval types (fig. 3; fig. 4, *c*).

THE DIFFERENT SPECIES OF TERMITES.

Of the many different species of termites in North America, the habits of only three are here considered in detail, namely, the common native termite (*Leucotermes flavipes* Kollar), a European termite (*Leucotermes lucifugus* Rossi), and the native southern species (*Leucotermes virginicus* Banks). These termites are greatly similar in form and habit and are all wood-destroying species of subterranean habits, with a relatively northern distribution. The winged sexed adults have strongly reticulated wings.[1]

In case of *flavipes* ("yellow foot"), these adults are clear castaneous-brown, 9 to 10 mm.[2] in length, including the wings, which are dull white in color, or plainly darkened, the borders being clear brownish, except at the base. The simple eyes or ocelli are separated from the faceted compound eyes by the width of their diameter. The swarm is usually in April or May. The soldiers are 6 to 7 mm. in length, the head being about once and two-thirds as long as broad.

In *lucifugus* ("light shunning"), the winged adults are dark blackish-brown, 11 to 12 mm. in length including the wings, the latter being dull smoky blackish with the borders black-brown. The ocelli are nearer to the compound eyes. This species swarms from October to April.

The southern smaller species (*virginicus*) is yellowish brown in color, being 7.5 to 8 mm. in length, including the wings, which are not darkened. The

[1] Subgenus *Reticulitermes* Holmgren.

[2] 1 mm.=one twenty-fifth inch.

swarm is usually in early June or later in the summer. The soldier is more slender than in *flavipes*, 4.5 to 5 mm. in length, the head being twice as long as broad.

In certain localities where several species of termites are known to occur the injury herein described can not always be attributed to a definite species, since specimens of the insects were sometimes not taken. This is particularly the case in the Southwestern and Gulf States and on the Pacific coast. It is probable that species not previously recorded as injurious will be found to be injurious, and it is known that undescribed species or those new to science occur.

COMMUNAL ORGANIZATION AND LIFE.

SITUATION OF THE COLONIES OR NESTS.

In North America termites do not construct large permanent nests of earth or mounds above ground, as in the Tropics. They make the nests in the wood of dead trees, decaying logs, or stumps in the forest; or in the foundation timbers of buildings, fences, or other structures of wood in contact with the ground; or in a labyrinth of underground passages in the earth, usually underneath wood or other vegetation. These nests are not as permanent as the mound nests, since the species have wandering habits and there are seasonal changes in the colony life. These species of termites (*Leucotermes* spp.) are essentially wood destroyers; their excavations usually follow the grain in solid wood. A protective outer shell of wood is always left intact by these blind, soft-bodied insects. Termites infest buildings by means of tunnels through the ground to and up through the foundation timbers, or, in case of foundations of stone or other impenetrable material, cover their pathway by means of "sheds" constructed of earth and excrement over the surface to the woodwork. Termites sometimes inhabit and enlarge the burrows of various other wood-boring insects.

SEASONAL VARIATIONS IN THE COLONY.

The center of activity in termite colonies changes with the seasons, due to varying needs as to conditions of warmth and moisture. In the eastern United States, in spring, when there is abundant moisture, outlying galleries of colonies are teeming with life, where, during the heat of summer, conditions would be too dry. In arid regions termites burrow deep into the ground; consequently in summer they bury themselves more deeply, going into the less exposed galleries. In the late autumn or at the beginning of winter (in northern Virginia, late October or early November) they enter the ground and do not come above ground till late in February or early March. Again, the colony readily migrates and the site is abandoned if conditions

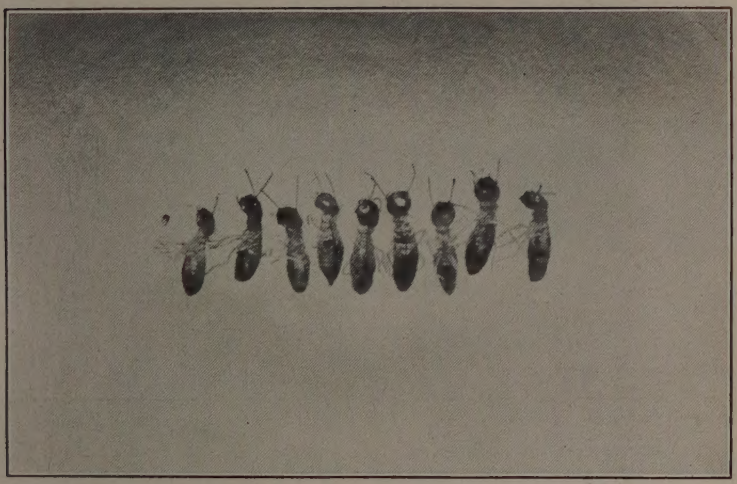


FIG. 1.—Mature "workers" of *Leucotermes flavipes;* chloroformed, living insects. Enlarged three times. (Original.)

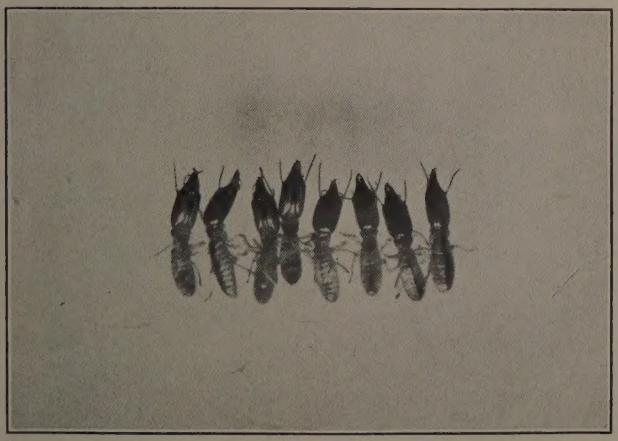


FIG. 2.—Mature "soldiers" of *Leucotermes flavipes;* chloroformed, living insects. Enlarged three times. (Original.)

TERMITES, WORKERS AND SOLDIERS.

FIG. 1.—Mature "king" of normal form, several years of age. Etherized specimen, enlarged six times. (Original.)

FIG. 2.—True "queen" with wing stubs and castaneous pigmentation to chitinized parts. Enlarged six times. (Original.)

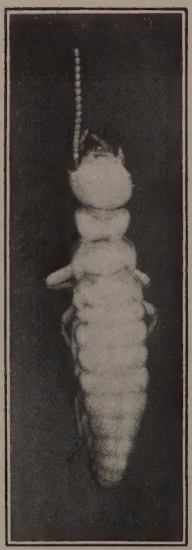


FIG. 3.—Neoteinic nymphal "king" showing tapering abdomen and characteristic pubescence. Enlarged seven times. Alcoholic specimen. (Original.)

FIG. 4.—Neoteinic nymphal "queen" with straw-colored pigmentation to chitinized parts. Enlarged seven times. (Original.)

become unfavorable. A single colony may be spread over an extensive area, and it is often impossible to define the limits of a colony. At higher altitudes in the Appalachian Mountains, in the canyons of the Southwest, and in high mountains in the West, termite colonies in the earth and under stones are more common. Colonies of Eutermes are commonly found in the earth.

NUMBER OF INDIVIDUALS IN COLONIES.

Average colonies probably contain several thousand individuals. In old, long-established termite colonies the number of individuals runs up into the tens of thousands. Young, recently established or incipient colonies are small and the increase in numbers is slow.

THE LIFE CYCLE.

THE METAMORPHOSIS AND CASTE DIFFERENTIATION.

The recently hatched termite larvæ (fig. 2) are all similar or undifferentiated, but are active from the first. At a later molt two types, large and small headed larvæ, can be distinguished. The former, after a series of molts and quiescent stages of comparatively short duration, develop to workers and soldiers, the latter to reproductive forms.

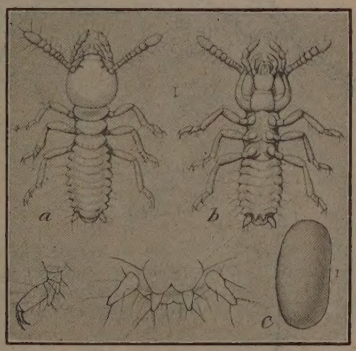


FIG. 2.—*Leucotermes flavipes: a*, Newly hatched larva; *b*, same from below; *c*, egg. All enlarged. (From Marlatt.)

There is no apparent or external change in the development of the worker, the larva being active and of the same form as the adult. There are marked changes, however, in the development of the soldier, with narrow, elongate head and saberlike jaws, from the round-headed worker-like larva. The winged, pigmented, sexed adults and the several types of neoteinic reproductive forms are developed from small-headed larvæ, there being still more radical changes, the former originating from nymphs of the "first form," with long wing pads, the latter from nymphs of the "second form" (Lespès) with short wing pads, or from young larvæ.

However, in all stages of the development of termites, what may be termed the "antlike" form of all castes can be recognized. There are no long inactive larval and pupal stages as in the ants and other social insects.

In the life cycle of termites there is so much variation in the development of the castes that there is consequently a rather complex

life history. Young are kept in a retarded, undifferentiated state and can be rapidly turned into supplementary or substitute reproductive forms of both sexes.

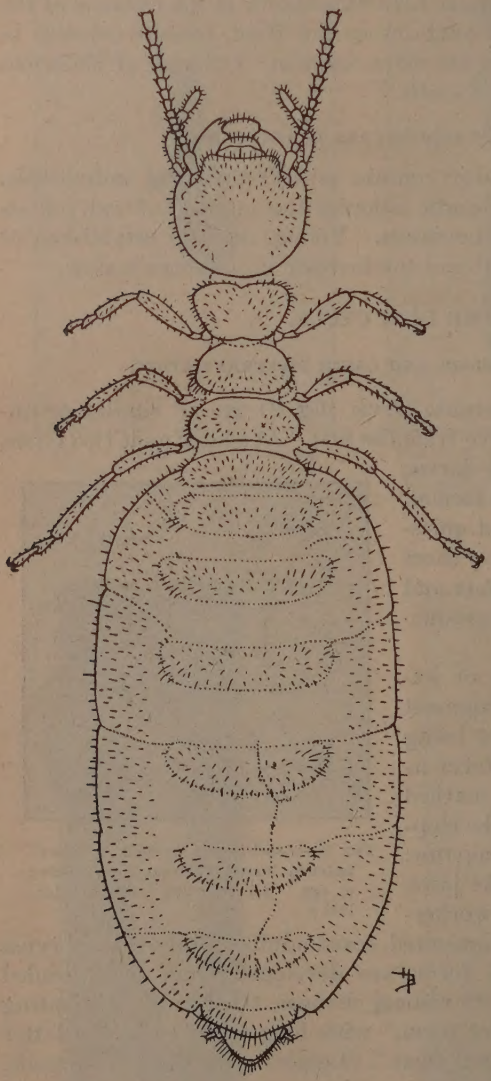


FIG. 3.—*Leucotermes flavipes:* Larval, worker-like reproductive form ("ergatoid queen," 9 mm. in length, alcoholic specimen). (Original.)

THE SEVERAL TYPES OF REPRODUCTIVE FORMS.

The nymphs of the first form, with long wing pads, develop to the winged sexed adults, which, after the swarm, lose the wings and become the kings and queens of the normal reproductive form. These normal kings and queens are blackish or brown in color, have eyes, and retain the stumps of their discarded wings (fig. 4, *a*).

From the nymphs of the second form, with short wing pads, are developed, probably by the workers, individuals of the substitute nymphal reproductive form of both sexes (Pl. II, figs. 3 and 4; text fig. 4, *b*). These nymphs of the second form are merely nymphs of the first form whose usual development to the pigmented, winged, sexed adults is retarded at a certain stage and never completed; the insects, instead, acquiring a pale yellowish or grayish color and becoming sexually mature normally after the sexed adults have swarmed. Individuals of this neoteinic reproductive form are apparently blind, not being destined to leave the parent colony, unless by underground tunnels.

Another type of substitute or neoteinic reproductive form, which greatly resembles the worker ("ergatoid"), is developed from young larvæ of the sexed forms. Of a pale yellowish or grayish color and having no wing pads (fig. 3; fig. 4, *c*), individuals of this larval supplementary reproductive form are apparently blind and never leave the parent colony, unless by underground tunnels.

In neither of the types of supplementary reproductive forms do the queens become as large as the normal queens, but there are usually many present in the same colony, as well as several males, or kings. The largest queen found in the United States of *L. flavipes* Kol. is only 14½ mm. in length and 4 mm. in width (measured while liv-

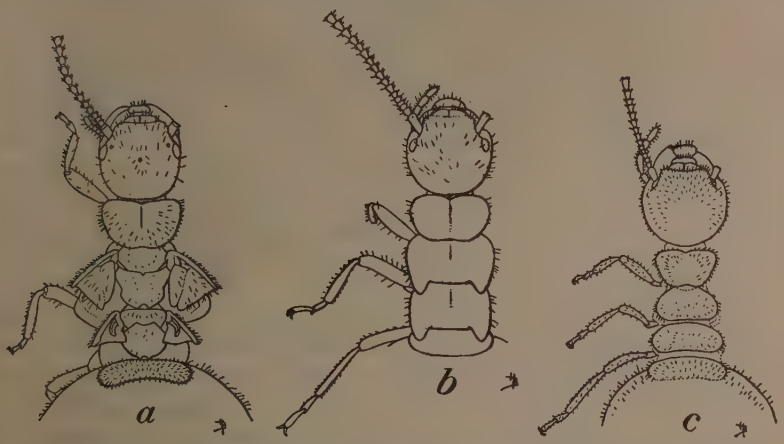


FIG. 4.—*Leucotermes flavipes:* Details of head and thorax of the three forms of reproductive females. *a*, True queen, or adult form, 14.5 mm. in length, wing stubs present; *b*, supplementary or "neoteinic" queen, or nymphal form, 9 mm. in length, wing pads present; *c*, worker-like or "ergatoid" queen, or larval form, 9 mm. in length, without wing pads. (Original.)

ing)—a queen of the normal type with wing stubs. Nymphal neoteinic queens 12 mm. in length (alcoholic specimens) and larval neoteinic queens 7 mm. in length (measured while living) are the largest that have been found of this species. The abdomens of nymphal queens are often distorted by the development of the ovaries and present an irregular, lopsided outline. These neoteinic forms of both sexes are probably developed to take the place of the normal forms in case of loss or possibly in the establishment of branch colonies; i. e., they may be impelled to migrate from overstocked colonies by means of underground passages. Queens of all these different types of reproductive forms are active even after the abdomen has become greatly distended.

DURATION OF DEVELOPMENT AND LIFE.

The workers, like the soldiers, complete their development in less than a year. The development of the nymphs of the reproductive forms (coming from larvæ that will mature the sexual organs) apparently requires two seasons.

For the development of the queen of the normal type to the maximum size several years are required.

There are no data on the length of life of individuals of the various castes, but the king and queen probably continue to live together for many years, under normal conditions, since they are of equal importance to the community.

THE SWARM.

At a certain season of the year the colonizing, winged, sexed individuals are impelled to migrate from the parent colonies in decaying logs, stumps, woodwork in buildings, etc. In case of the widely distributed species *flavipes*, the colonizing forms emerge from colonies in April or early in May in the Southern States or the last of May or early June in the Northern States; the swarm usually occurs in the morning or in the middle of the day, in case of large colonies usually lasting about two hours. The southern species *virginicus* swarms in early June, but sometimes as late as the first part of August in northern Virginia; while the species *lucifugus* of Mediterranean Europe swarms from the middle of October to April in Texas, Kansas, Colorado, and on the Pacific coast, usually after showers. Often several swarms occur from the same colony, extending over a period of four weeks. In colonies in infested buildings the winged males and females usually emerge about one month before the swarm occurs outdoors.

THE FOUNDATION OF NEW COLONIES.

After the adults have rapidly emerged from the parent colony, from crevices in the infested wood, in a swarm of enormous numbers and have flown a short distance in an irregular, "wobbly" manner, they fall to the ground. The flight is usually not farther than from 75 to 100 feet, but the insects, usually flying low, are sometimes carried farther by the wind. Both during and after the flight they are promptly preyed upon and destroyed by many insectivorous animals which are attracted to the cloud of flying insects, resulting in an enormous mortality.

Among these enemies are many species of wild birds which are attracted to swarms of termites in woodland and greedily capture the flying insects in midair.

Hagen states,[1] in mentioning an exceptionally large swarm which occurred in Massachusetts:

> Last Sunday, May 19 (1878), on North Avenue, near Everett Street, there passed just before the windows of the house of Prof. Hedge, while the family was at breakfast, a cloud of flying insects, dark enough to draw the attention of the family. They went out of doors and saw the cloud coming from the east, a part alighting on the garden steps. Some of the insects were preserved alive and sent to me, and proved to be *Leucotermes* (*Termes*) *flavipes*.
>
> The phenomenon was more remarkable, and their attention more strongly called to it, by finding 15 different kinds of birds following the insects so eagerly that even the presence of the family did not disturb them. Besides the common robbins, bluebirds, and sparrows, were others not seen before near the house. The birds caught the Termes partly in flight, partly on the ground, and the robins were finally so gorged in appearance that their bills stood open.
>
> I think such a flock of birds following an emigration of white ants—which is very common in the Tropics—has never been noticed here. Perhaps the very early appearance of white ants (commonly they arrive in the middle of June) explains the hunger and eager persecution of the birds, as other insects are still rare.

The Biological Survey has found that termites constitute part of the food of at least 27 of the species of birds living in the United States. The woodpeckers are represented in this list by 8 species, and no fewer than 1,100 termites have been found in a single stomach of the common flicker. Other birds consuming noteworthy numbers of termites are the nighthawk (largest number found in one stomach, 220), chimney swift (160), tree swallow (75), barn swallow (50), and bank swallow (50). The complete list of birds is as follows: Wood duck, hairy woodpecker, downy woodpecker, red-cockaded woodpecker, Nuttall's woodpecker, pileated woodpecker, flicker, red-shafted flicker, gilded flicker, nighthawk, chimney swift, kingbird, Cassin's kingbird, black phœbe, western wood-pewee, horned lark, meadowlark, song sparrow, scarlet tanager, barn swallow, tree swallow, bank swallow, mockingbird, catbird, Carolina wren, wood thrush, and bluebird.

Barnyard fowls also are attracted to the swarming insects and capture large quantities of the insects as they emerge. Lizards (in California and in southeastern Texas) have been observed to devour swarming termites. Many different species of spiders also prey on the insects after they alight on the ground. Among the insects, ants[2] greatly diminish the number of the colonizing individuals at the time of the annual swarm. Centipedes have been observed in Virginia to carry away in their mandibles workers from a disorganized colony; they are sometimes found in the covered earthen runways of termites. Crickets[3] have been recorded feeding

[1] Hagen, H. A. Note.—*In* Proc. Soc. Nat. Hist. Boston, v. 20, p. 118, Nov. 27, 1878.
[2] Species of *Cremastogaster, Camponotus,* and *Formica.*
[3] *Gryllus pennsylvanicus* Burm.

on swarming adults (*lucifugus*) in Kansas (McCulloch). Probably there are many other insectivorous animals that reduce the enormous number of winged termites.

While clumsy in flight, termites are able to run rapidly, but apparently never wander great distances. Further, even some of those pairs that escape being devoured fail to become established in new colonies because of unfavorable moisture conditions in the incipient colony.

The male is attracted to the female, and after the flight, either before or after the now useless and retarding wings have been discarded by being pried off at a suture near the base, tirelessly and closely follows her about. In this manner the insects separate into pairs and become established in shallow cells in the earth, usually under decaying pieces of wood, in holes in the wood, or under moist bark, thus independently establishing new colonies.

The female in seeking the site of the new colony is sometimes followed by more than one male, and in shallow cells excavated by these reproductive forms there may be one female associated with two males or vice versa.

MATING.

During the first stages of colonization both the male and female are active, forage for themselves, and are apparently equally important in the establishment of the new colony and the independent rearing of the first brood of young.

The habitation of the male and female or incipient colony is called the "royal cell," since it is occupied by a single parent pair, the especially developed "king and queen," which have originated from the winged, sexed adults after the swarm. The first brood is reared within the confines of this small chamber. In this type of reproductive form, after the pair have become established together, there is further sexual development and the abdomens of both sexes increase slightly in size. In case of the queen there is a later considerable post-adult growth.

Unlike the other social insects, the sexual relations of the male and female termite are continued. Copulation probably does not take place until about one week after the swarm and the establishment of the pair in the royal cell, but is repeated at irregular intervals over a period of many years.

THE RATE OF EGG LAYING.

Egg laying in newly established colonies in case of the species *flavipes*, in the southeastern United States, begins about the middle of June or July; and in late June to July, or August—unhatched eggs being present till the middle of August—in incipient colonies of

virginicus, varying with the season, or about one and one-half months after the swarming. Usually only 6 to 12 eggs compose the first batch; they are deposited in a cluster in the royal cell and are carefully tended. The eggs begin to hatch in about 10 days after they are laïd.

Most larvæ of the first brood develop to workers and a few to soldiers. While the recently hatched young are active they are dependent on the care of the parents for food. During the development of the first brood the male continues to share the cell with the female and both are active. The abdomen of the queen at this time is not markedly distended. Egg laying ceases after the first batch is laid and is not resumed until the first brood of young is mature, i. e., about six months after the first eggs were laid. Copulation and egg laying occur at shorter intervals and more frequently from now on and the abdomen of the queen gradually enlarges, eventually becoming greatly distended through constant care and feeding by the workers and the enormous development of the ovaries. These queens never reach the size attained by species in the Tropics.

The rate of egg laying and development of the young and active queen of this normal type is slow and the new colony is small. Even after the rearing of the first brood the increase in numbers is not rapid. The capacity for egg laying becomes gradually increased as the abdomen enlarges, but queens of these species (*Leucotermes*) never entirely lose the power of locomotion. An isolated, fully developed queen of *flavipes* (approximately 14 mm. in length) was capable of laying, after capture, over 1 dozen eggs between 5 p. m. and 9 a. m. Hence even in large, well-established colonies the rate of egg laying of normal queens is not remarkable. However, where there are many neoteinic reproductive forms of both sexes in colonies the increase is rapid and extensive. The rate of egg laying is not comparable to that in tropical species.

Since no types of the reproductive forms ever entirely lose the power of locomotion, there is, in consequence, no permanent royal cell, but these forms are usually in a cell in the more solid wood. In winter they probably are to be found below the frost line in the ground, where termites pass the cold season in a labyrinth of galleries. Wood-boring ants[1] are to be found in frozen masses in galleries in wood, but the soft-bodied termites pass the winter below ground in a state of sluggish activity or are more or less dormant.

THE PERIOD OF MAXIMUM EGG PRODUCTION.

In large, long-established colonies of *flavipes* in the eastern United States eggs and newly hatched larvæ (fig. 2) are to be found

[1] *Cremastogaster* sp. and *Camponotus* sp.

from April to October; in incipient colonies of *flavipes* in northern Virginia the first eggs are laid by the middle of June or July, or from the last of June to July or August in case of *virginicus*.

In northern Virginia, in well-established colonies, the period of maximum egg production of both species is from the middle of May to early September; that is, during the warm months.

In infested buildings occupied by man termites are able to maintain their activity during the entire year, and it is probable that eggs are produced in every month of the year.

The eggs are tended by the young parent adults in the royal cell in incipient colonies, but in long-established colonies the eggs are removed by the workers and deposited in clusters in the outlying galleries of the colony where conditions are best suited for rapid hatching.

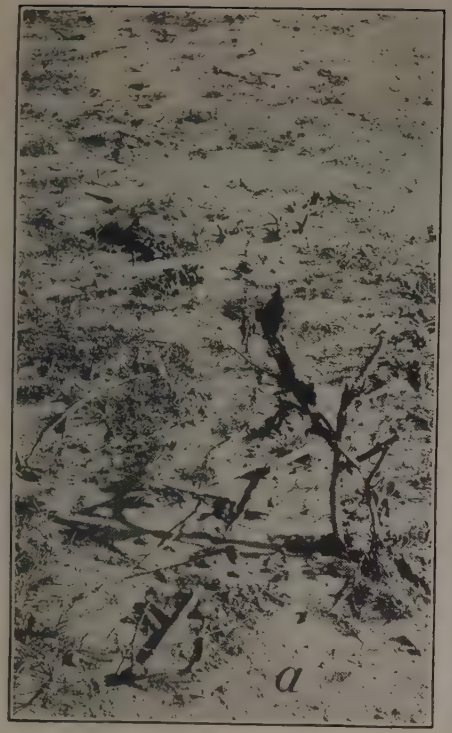
GEOGRAPHICAL DISTRIBUTION.

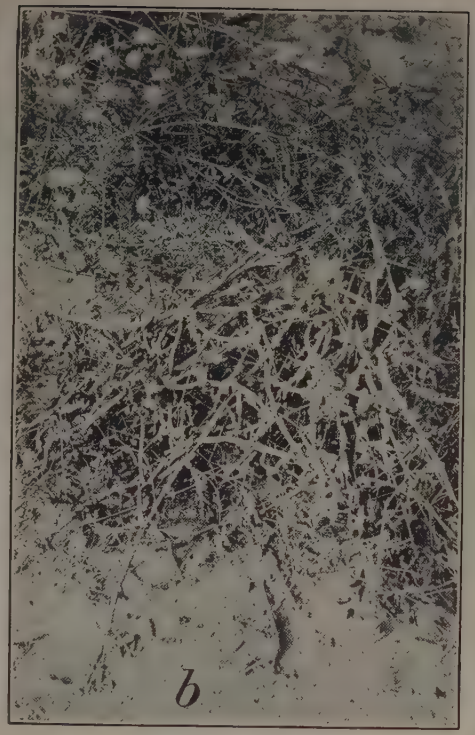
Termites are widely distributed over the world, but increase in numbers as the Tropics are approached. There are many species in North America. Our common species *flavipes*, according to Marlatt, is very widespread over North America, "occurring from the Atlantic to the Pacific and from Canada southward to the Gulf. It has been found on the mountains of Colorado and Washington at a height of over 7,000 feet." This termite has been introduced into Europe, being also reported to occur in Japan. S. Hozawa states[1] that *Leucotermes spretus* Kolbe is the only representative of the genus *Leucotermes* in Japan, and that *L. flavipes* has not been found in Japan. Another termite closely allied to *flavipes*, *lucifugus*, occurring in the Mediterranean countries of Europe and also in western France and Hungary, but being especially abundant throughout southeastern Europe, according to E. A. Schwarz, originated in Mexico. This insect has also been introduced into North America (western United States). In the United States *lucifugus* is found in Texas, Arizona, Kansas, Colorado, and southern California, and proably occurs elsewhere. This species also occurs at high altitudes in Colorado, i. e., about 6,000 feet. The native species *virginicus* is recorded from the District of Columbia, Maryland, and Virginia, but probably has a wider distribution.

In the prairie regions of Texas and Arizona a tube-forming termite[2] lives in the ground, in pasture tracts, feeding on the roots of grass and other vegetation, often being found under and within dry cow dung and under stones. A characteristic habit of this grass-destroying species is to cover the stems and roots of vegetation with

[1] Jour. of the College of Science, Tokyo Imperial Univ., v. 35, art. 7, p. 82, Apr. 30, 1915, "Revision of the Japanese Termites."

[2] *Hamitermes tubiformans* Buckley.





TERMITE SHELTER TUBES.

Stems of both living and dead vegetation incrusted with earthen tubes of the termite, *Hamitermes tubiformans*. Esperanza Ranch, Brownsville, Tex., June 12, 1904. Photographs by H. S. Barber. (Original.)

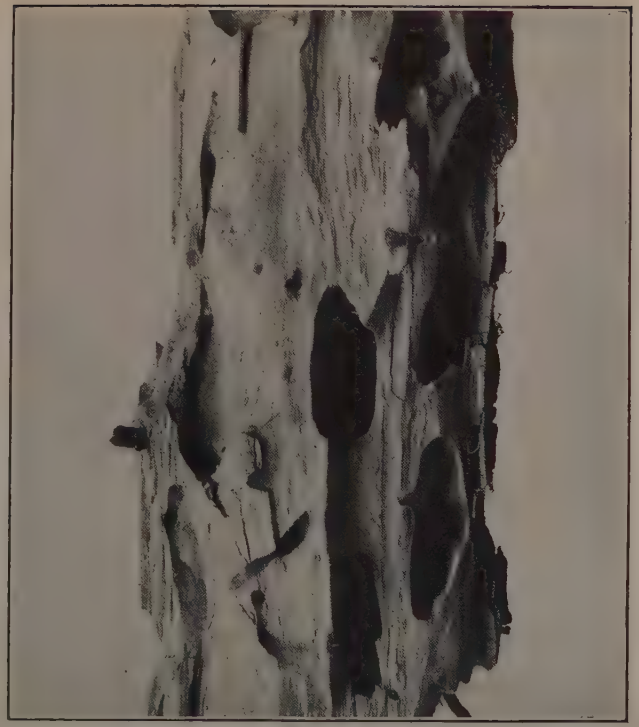


FIG. 1.—Chambers excavated in Arizona cypress (*Cupressus arizonica*) by *Calotermes* sp. Catalina Mountains, Ariz. (Original.)

FIG. 2.—Damage by termites (*Leucotermes* sp.) to sound dry red-oak molding from door casing, showing walls of runways coated with earth mixed with finely digested excreted wood. (Original.)

tubes of small diameter, constructed of earth and excrement (Pl. III). M. Chrisman has found these termites in Arizona under similar coverings at the base of mesquite stumps, fallen limbs, twigs, etc.; always on the dry wood, but not in cells in the wood, apparently eating only the outside. Many other termites occur in North and Central America.

ECONOMIC IMPORTANCE OF TERMITES IN THE UNITED STATES.

While termites damage a great variety of wooden structures, stored books, documents, paper, and other material, as well as occasionally injuring or killing living trees, shrubs, and growing crops, the principal and most serious damage is to foundation timbers and the woodwork of buildings occupied by man and the contents or material stored therein. Similar damage to other construction timber in contact with the ground is considerable in the Southern States. Apparently, it is only occasionally that these insects attack living trees and shrubs, growing crops, or other vegetation, and then only because the land has been recently cleared and there is much decaying wood or humus in the soil; or, according to C. L. Marlatt, of the Bureau of Entomology, in the case of corn in the prairie region of Kansas, because the insects are present in enormous numbers and have been breeding in the heavily sodded soil, where they feed on the roots of the vegetation. Sometimes this injury to growing corn is due also to the method of plowing under old stubble.

Hence, in the following account of general damage to a great variety of stored material and products, as well as living crops, it should be borne in mind that such damage is usually occasional, and then only local and not in general a serious problem.

DAMAGE TO BUILDINGS AND OTHER STRUCTURES OF WOOD.

Damage to foundation timbers, flooring in basements, and other woodwork of dwellings occupied by man, as well as to other buildings, is common and occasionally serious in the eastern and southern portions of the United States, especially in the South Atlantic and Gulf States. Injury of this type has been recorded as occurring in large cities,[1] as well as in rural regions, as far north as Manchester, N. H., and the shores of the Great Lakes (Benton Harbor, Mich.).

[1] Records in the correspondence files of the Bureau of Entomology and branch of Forest Insect Investigations include Benton Harbor, Mich., Manchester, N. H., Boston, Mass., New York, N. Y., Atlantic City, N. J., Philadelphia, Pa., Wilmington, Del., Baltimore, Md., Washington, D. C., Wheeling, W. Va., Cleveland, Cincinnati, and Dayton, Ohio, Indianapolis, Jeffersonville, and South Bend, Ind., Cazenovia, Ill., St. Louis, Mo., Charlotte, N. C., Charleston and Spartanburg, S. C., Louisville and Franklin, Ky., Memphis, Tenn., Augusta and Savannah, Ga., Montgomery and Birmingham, Ala., Vicksburg, Miss., Jacksonville, Miami, and St. Augustine, Fla., New Orleans and New Iberia, La., Beaumont, Dallas, and San Diego, Tex., Little Rock and Van Buren, Ark., Oklahoma City and Wewoka, Okla., Manhattan, Kans., Colorado Springs, Colo., Salt Lake City, Utah, and localities in southern California.

W. D. Hunter stated on November 6, 1915: "The recent hurricane injured practically every building in the city [New Orleans, La.] more or less, and hundreds were completely demolished. * * * Many of the exposed beams were mined by insects and in many cases at least this weakening of the timbers was an important contributory cause of the loss." Much of this damage was probably due to termites.

Termites usually gain entrance to buildings from colonies outdoors, and since the workers can extend subterranean galleries for comparatively long distances, it is often impossible to trace the insects to the outside source. However, these galleries, constructed in search of moist or decaying wood, originate in decaying stumps, poles, fence posts, boards, or other decaying wood, or in the earth not very far away.

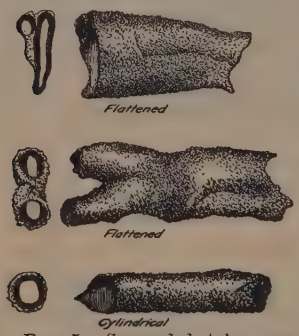


FIG. 5.—Suspended tubes constructed by termites (*Leucotermes flavipes*) of earth and excreted wood, Elkins, Va. Natural size. Drawn by Miss E. Hart. (Author's illustration.)

By means of these subterranean tunnels infestation by way of wooden beams, joists, or supports of porching or steps in contact with the ground is effected. Termites can even pass over impenetrable surfaces, such as stone, brick, or concrete foundations, by means of small sheds or tubes constructed of earth and excrement on such surfaces or by means of suspended tubes (fig. 5). Sometimes ingress is gained through cracks in concrete where foundation timbers are imbedded in this material. These insects have even been recorded by Forbes as boring several feet through the mortar or cement between the stones in foundation walls and brick partitions of the Statehouse at Springfield, Ill., and by Grant as perforating the mortar of the brick walls of a Missouri Pacific Railroad engine house (probably through cracks or where the cement was disintegrated). There are several records of termites piercing the lead covering to telephone cables in Australia and the United States (Savannah, Ga.).

Since their work is hidden, the presence of termites is often not discovered till the damage is beyond repair. Thus beams, flooring (Pl. XV, p. 28), walls and other woodwork, even up to the second and third floors, and furniture are reduced to mere outer shells, the interior being completely honeycombed; often these intervening longitudinal layers of wood that are left uneaten are reduced to the thinness and consistency of paper. Sometimes the settling of floors or the collapse of joists is the first indication that the building is infested. This often necessitates extensive repairing or complete rebuilding after tearing down and removing the infested timber.

However, the annual emergence of the winged adult termites is an indication of infestation and the point of emergence shows the approximate location of the infested timber. The presence of the earthlike tubes on timber or rock foundations of buildings is also a warning that the building is infested by termites.

While injury by termites in tropical regions affects not only the soundness of the building,[1] but the dry, hard wood of furniture and other contents as well, in this country attack is usually begun in moist or decaying foundation timbers. However, termites are able to extend their burrows throughout dry, hard wood and other dry substances, provided that there is access to moisture elsewhere; i. e., they make use of a mixture of moist frass and earth in creating more favorable conditions. Thus there is, in infested buildings, occasional damage to flooring, wooden partition walls, wainscoting, molding, door casing (Pl. IV, fig. 2), sills, window and door frames, wooden lath and wall plaster,[2] as well as to tiling o rother interior construction made of wood pulp (Pl. V), furniture, wall paper, starched cotton curtains, and various stored material.

In infested buildings, where they have worked for several years, the insects having usually entered the house by means of joists or stringers in contact with the ground or set in concrete, work is begun in the flooring next to the walls, and burrows are excavated in toward the center of the room. The woodwork of coal bins in cellars sometimes becomes infested and is the cause of the insects gaining entrance to the flooring and other woodwork of the building.

Flooring, other woodwork, and furniture in infested buildings above boilers or furnaces where the temperature is high or the wood is moistened by hot steam are especially liable to attack.

In addition to the private residences, hotels, and business houses occupied by man, termites infest factories, granaries, barns, greenhouses, sheds, outhouses, and other wooden structures. The framework of wooden greenhouses, which are always warm and moist, is especially liable to attack and may be seriously damaged. The injury in these structures is extended to the wooden plant benches, plant tubs, label sticks, and sometimes to the growing plants.

Many other structures of wood are damaged by termites, any timber in contact with the ground being especially liable to attack.

[1] *Calotermes marginipennis* Latr., recorded from Central America (Mexico and Panama) and California, is especially injurious to the woodwork of buildings and other structures, and such injury in the Southwestern States and in California may be due to this or closely allied species of Calotermes. This species excavates chambers in the interior of the solid wood, rather than honeycombing it as do species of Leucotermes. (Pl. IV, fig. 1.) An indication of the infestation by Calotermes is the small oval sculptured pellets of excrement expelled by the insects. There is a record of damage to painted dry siding of a railroad business car at Los Angeles, Cal., by Calotermes, Apr. 6, 1915, and to the pine sill of a porch at Palm Beach, Fla., May 4, 1915, by *Cryptotermes cavifrons* Banks.

[2] In Baltimore, Md., and in Charlotte, N. C., the plaster laid on wood and patent metal lathing was probably only incidentally bored to allow the colonizing sexed adults to emerge at the time of the annual swarm.

Among these may be listed construction timber in bridges—there are only two actually recorded cases, one near Cambridge, Mass. (H. A. Hagen), and the other near Cleveland, Ohio (F. L. Odenbach)—wharves, and like structures; telephone and telegraph poles and poles used by electrical and other companies (in New York, New Jersey, Pennsylvania, West Virginia, southern Illinois, Indiana and Ohio, Missouri, Nebraska, California,[1] and in general the Southern States[2]); hop and bean poles; mine props and other timbers on the slope of incline mines (in West Virginia and Alabama); posts, lower rails, and boarding of fences; lumber piled on the ground; crossties (New Jersey, Virginia, Maryland, and the Southern States); improperly creosoted wood paving blocks (used as flooring in a factory building in Atlanta, Ga.; the wooden boxing or conduits of cables in the ground, to the detriment of the insulation; the woodwork in wells; wooden silo tanks; the ridge poles of tents, and tent pins (in desert near Boise, Idaho); wooden tree boxes; wooden beehives (near Shelbyville, Tenn.), the last being infested through wooden cross-pieces lying on the ground.

According to F. H. Chittenden much injury is done by white ants (*lucifugus*) in hopyards. The dead roots, trellis poles made of redwood, and pine string pegs are attacked in California.

There is evidence that termites not only injure man's habitations while alive, but also infest the last resting place of man on this earth, namely the pine boxes and coffins of the dead. Derry records extensive damage to skulls and bones generally by termites in graves in Egypt and Nubia,[3] and these insects have been observed in several localities swarming in cemeteries. Furthermore, they often burrow deep into the earth, especially where they can follow down decaying wood, as in the woodwork of wells, etc. G. A. Dean, entomologist of the Kansas State Agricultural College, Manhattan, Kans., states that McCulloch observed a swarm of termites in a cemetery at Anthony, Kans., on January 19, 1914, in which the winged insects[4] came out in enormous numbers and the ground was actually covered with them in several parts of the cemetery. The temperature at this time was about 70° F.

DAMAGE TO STORED MATERIAL.

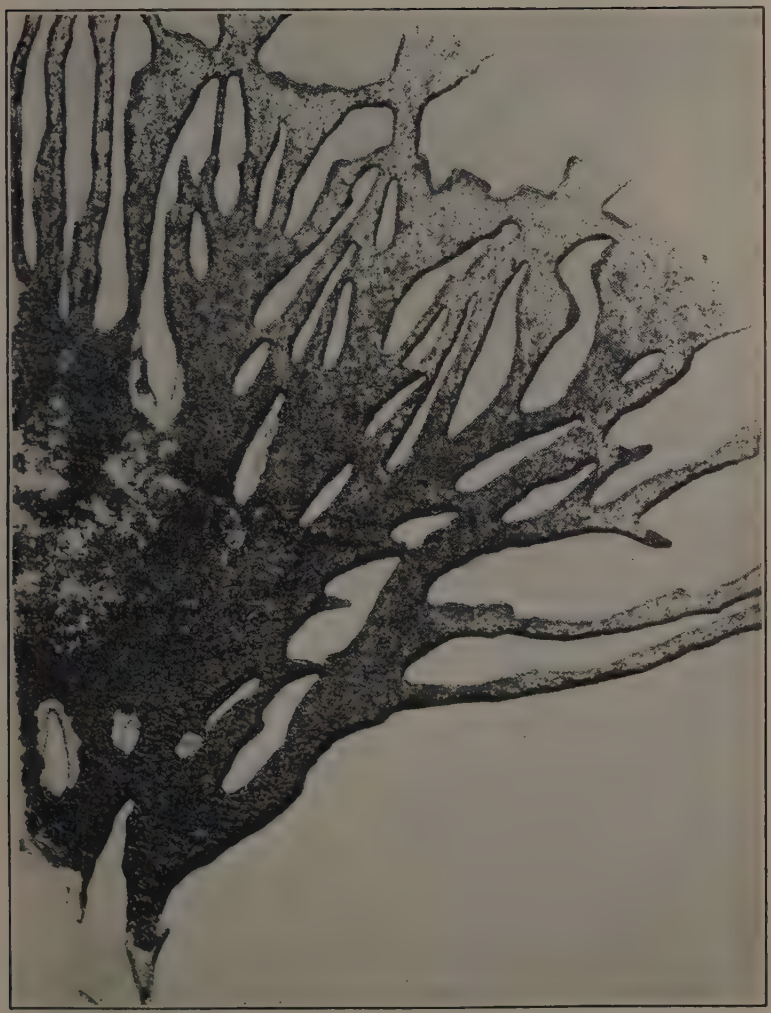
Wooden electrotype blocks (in New York, N. Y.) and other wood products, books in libraries or elsewhere, pamphlets, paper, documents (Pl. VI, fig. 1), and plans (Pl. VI, fig. 2), wood-pulp products,

[1] In California termite damage includes also that by *Termopsis angusticollis* Walker.

[2] In southern Georgia and the Gulf States termite damage to poles of bald cypress and southern white cedar (*Chamaecyparis thyoides*) includes also that by *Calotermes* sp.

[3] In many graves in Egypt and Nubia bones are found to be covered with a shell of earth; also in mummified bodies, where less bitumen or other preservative substances were employed, termites were able to make way through the cloth in which the body was wound, damage always being associated with earthwork and tunnels.

[4] Probably *Leucotermes lucifugus*.



PRESSED WOOD-PULP TILE MINED BY TERMITES. BILOXI, MISS. (ORIGINAL.)

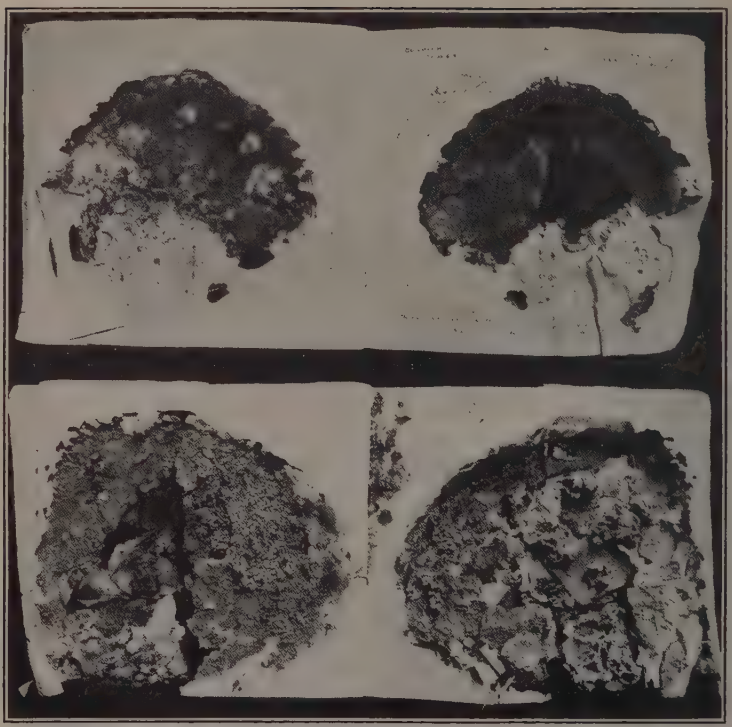


FIG. 1.—Termite work on railroad documents, Victoria, Tex., November 10, 1904. Photograph by W. E. Hinds. (Original.)

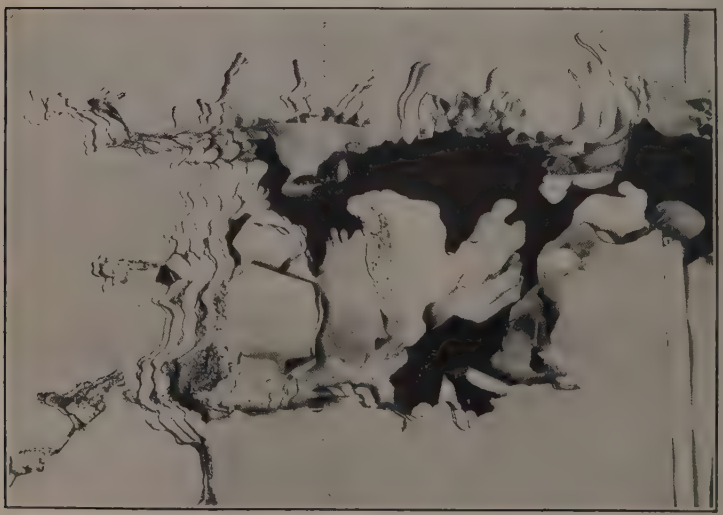
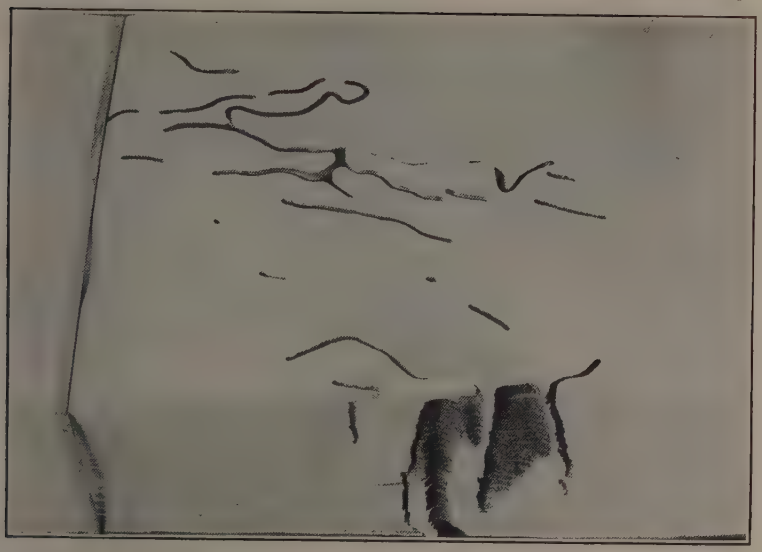
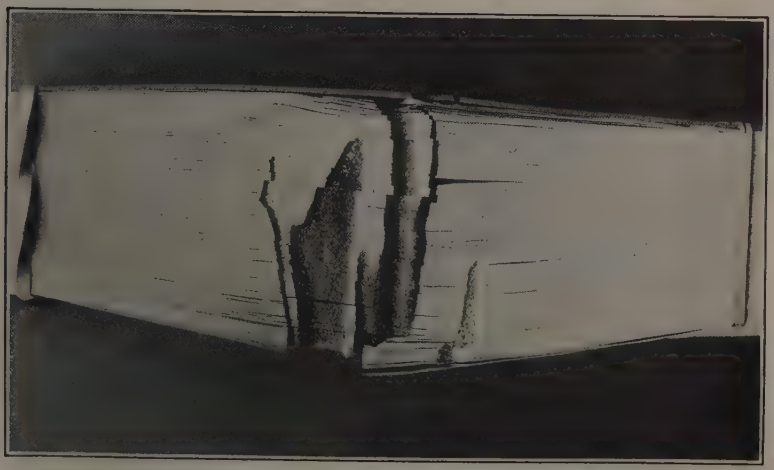


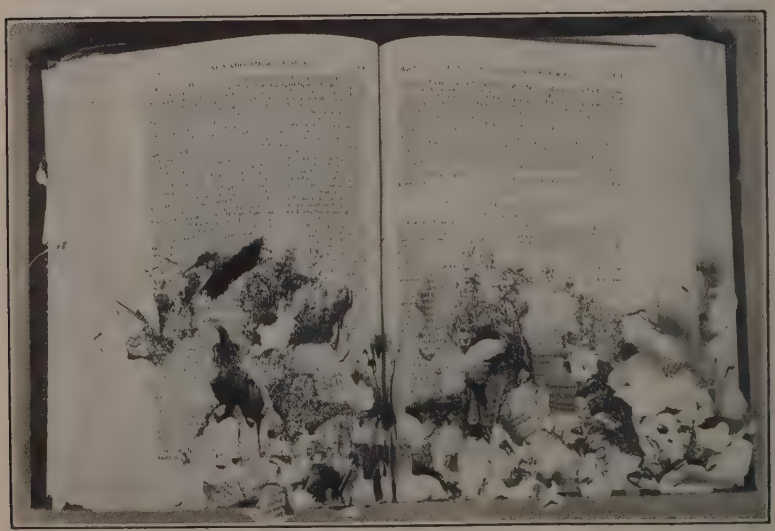
FIG. 2.—Plans at Washington (D. C.) Navy Yard damaged by *Leucotermes flavipes*. January, 1913. Photograph by C. H. Popenoe. (Original.)





Stored paper burrowed by termites (*Leucotermes flavipes*), the edges of the mines being covered with excrement. Atlanta, Ga. (Original.)

DAMAGE BY TERMITES TO STORED PAPER.



Book from library at Van Buren, Ark., ruined by termites. June, 1915. Views of book open and on end. (Original.)

VIEWS OF BOOK IN LIBRARY DAMAGED BY TERMITES.

pasteboard, rolls of cloth, and other fabrics, clothing, shoes, and other leather products, as well as food stored in dark, damp basements or similar moist places where the ventilation is poor, are sometimes seriously injured or destroyed by termites. At St. Louis, Mo., December 21, 1889, according to a correspondent of the Bureau of Entomology, termites bored through a full bolt of "Conestoga" ticking into wood about one-fourth to three-eighths inch in thickness. The ticking had been lying on a shelf for about a month and was covered with excrement where bored. Cotton yarn stored in a mill (Raleigh, N. C.) and cotton goods (Vincennes, Ind.) have been reported to be injured by termites. Entire stacks of books and paper (Pls. VII and VIII) are often completely penetrated and ruined by the burrows of these insects. W. S. Abbott has referred me to an instance at Manchester, N. H., where, according to E. J. Burnham,[1] documents were damaged in a cement vault in a basement, the insects probably entering in with the pine boards sheathing the vault. Similar cases have been recorded in Washington, D. C., and elsewhere. Termites usually infest this class of material indirectly through the moist or decayed wooden flooring, shelving, or casing on which the products are stored. At Cazenovia, Ill., paper lining under rugs and the carpets and rugs, where in their path, were eaten through, the insects coming up through the infested flooring underneath.

Some unusual cases of injury to other stored products have been furnished by F. H. Chittenden, in charge of Truck Crop and Stored Product Insect Investigations in the Bureau of Entomology; i. e., samples of flour received from New Orleans, La., in which were large lumps containing burrows made by *Leucotermes flavipes*, a few dead insects being still present in the same. The sacks containing this flour were unloaded on a platform under cover about the middle of November. The bottom sacks were cut as with a knife immediately above the floor and in these bottom sacks the lumps of flour were found that contained the white ants. Some sacks and bags received containing rice were injured in about the same way. The bottoms were eaten out of the sacks and the insects, by means of an adhesive substance, caused the rice to stick together at the bottom of the sacks. Another case of injury to stored rice occurred at Baton Rouge, La. Peanuts in store have also been attacked. On May 9, 1910, many layers of damaged bandage muslin (Pl. XIV, fig. 2), which had been lying on a wooden floor, were received from a Philadelphia hospital. The correspondent stated that this had happened a number of times.

[1] Burnham, E. J. Damage by white ants. *In* Nature Study, v. 3, no. 2, p. 201–203, Manchester, N. H., April, 1903.

DAMAGE TO FRUIT, NUT, SHADE, AND FOREST TREES.

Termites occasionally injure a great variety of living trees, bushes, and shrubs. In Florida, according to H. G. Hubbard, termites have caused considerable damage to newly planted groves of orange trees, the bark being eaten away about the collar and root and the tree completely girdled. There have been many records since then of injury to young orange trees in newly cleared land (Marlatt). Similar damage by termites[1] has been recorded to apple, pear, cherry, and plum trees in the Southern States and California,[2] the roots being attacked or the trees injured near the base. H. S. Smith states[3] that "termites were reported to be damaging lemon trees in the vicinity of Germantown" (California). On May 17, 1890, a piece of solid pear root damaged by termites was sent to the Bureau of Entomology from Mineral Park, Mohave County, Ariz. On May 9, 1902, a similarly damaged root of apple stock was submitted to the bureau from Moran, Okla.

Such damage is more common in the new soil of recently cleared woodland containing old decaying stumps or much humus. Similar damage by *Leucotermes* spp. is recorded to pecan, chestnut, and walnut.

Comstock records damage of the same kind to guava bushes in Florida, at or just below the ground.

In cities shade trees in great variety are injured by termites, the insects infesting the roots and the heartwood at the base of injured trees. Sometimes the infested trees are plastered with earthlike tubes or galleries.

In the forest termites rapidly[4] render insect, fire, and disease killed timber unmerchantable. They also damage the roots and lower trunk of injured living trees, especially oak and chestnut, sometimes following the attack of large wood-boring beetle larvæ.[5] In a letter dated October 24, 1915, A. B. Champlain states: "Termites are very bad on hickory saplings at Lyme, Conn. They quickly attack the infested trees, utilizing the Magdalis galleries, Goes galleries, or any other mode of entrance; in wounds on green trees as well as in trees of every stage of decay." Where the heartwood is decayed in living trees or in dead standing trees termites will work for considerable distances above ground (40 to 50 feet), completely honeycombing the interior. (Pl. IX, fig. 1.) The earthlike tubes, in the form of

[1] *Leucotermes* sp.

[2] Essig, E. O. Injurious and Beneficial Insects of California. Supplement Mo. Bul. State Com. Hort. California, v. 4, no. 4, 541 p. (p. 28–29), 503 figs., 1915. Damage by *Leucotermes lucifugus* to various species of fruit trees; i. e., apricot, cherry, lemon, orange, peach, and pear.

[3] Smith, H. S. *In* Mo. Bul. State Hort. California, v. 4, no. 1, p. 53, Jan., 1915.

[4] The rapidity of destruction varies with the resistance of the wood of the species of tree and the geographical locality.

[5] Prionidæ.

longitudinal tunnels or viaducts, constructed by termites often can be observed between crevices in the bark of infested dead and living trees to a considerable distance above the ground.

DAMAGE TO FIELD CROPS.

In the Southern States termites occasionally injure the stems and roots of a great variety of apparently healthy field crops, including both grain and truck crops, among which may be listed corn, cotton, sugar cane, rice, grasses, and a great variety of garden vegetables. In Kansas the species *lucifugus* is reported to inhabit dry vegetable and fibrous substances.

Injury of this character has been only occasionally recorded, and in consequence there has been, and is, considerable doubt as to whether termites are capable of attacking perfectly healthy living plants, it being usually considered that the plants attacked were previously either diseased or injured. However, termites are capable of such primary attack, although such injury in every case is not necessarily primary.

Comstock, as early as 1879, stated that in the Southern States termites infest living plants such as sugar cane (Florida) and pampas grass (Texas), attacking that part of the plant which is at or just below the surface of the ground. The bases or stalks of pampas grass are hollowed; in case of sugar cane the most serious injury is the destruction of the seed cane. On July 6, 1915, T. E. Holloway found workers and soldiers of *Leucotermes* sp. in burrows of Diatraea in sugar cane at New Orleans, La.

Kent states that at Roxie, Miss., termites[1] destroyed a good many cotton stalks during the summer of 1887, attacking the stalk just below the soil and eating out the interior, which would kill the plant in every instance.

F. H. Chittenden records injury to roots of cranberry at Bordentown, N. J.; also, in cases where the species of termite was not determined, to young squash plants at Brownsville, Mercedes, and Mission, Tex.

COTTON.

W. D. Hunter, in charge of Southern Field Crop Insect Investigations, has furnished the following field notes.

H. Pinkus, on June 22, 1910, in a cotton field on an irrigated farm at Lampasas, Tex., noticed many dead plants and some dying at certain places between healthy plants. Upon digging up the ground he discovered termites[2] destroying the stem about 2 inches below the surface of the soil, a hole being bored through the stem and into the heart of the plant; some plants were recently killed. Pinkus stated that on June 30, 1910, in a cotton field at Granbury,

[1] *Leucotermes flavipes.* [2] *Leucotermes lucifugus.*

Tex., a number of dead plants were found that had been killed by termites. (Pl. X, fig. 1.) On July 2, 1910, in a field at Pearsall, Tex., a large cotton plant that had borne fruit was found already wilted, evidently very recently. When the soil was dug up about 3 inches deep from the surface and the plant moved, the stalk came off, clean cut, and the termites came out of its heart; the lower part of the plant was gone and only a few small roots could be found. E. S. Tucker states that on July 12, 1910, an examination of a cotton field at Plano, Tex., showed termites present and working in a few roots that had been killed by a root-rot disease; the stalks had been dead and dry for some time. The roots were badly bored. (Pl. X, fig. 2.)

POTATOES.

Injury by termites to potatoes has been recorded by C. L. Marlatt,[1] who states that a very common form of injury to those growing in rich soil or where there is a considerable quantity of decaying vegetable matter has often been noted. F. A. Marlatt discovered that white ants caused the damage, the injury to the tubers having the form of scars or pits covering the surface, the pits varying in shape from irregular holes to long, irregular excavations, sometimes extending far into the potato, but commonly to a depth of from one-eighth to one-fourth of an inch. In all cases these pits are more or less overhung and covered by the dead and dying skin, and are also lined with the cellular tissue of potato, showing that the insect cares most for the starch and water of the tuber. C. L. Marlatt now believes that the termite injury to the potato may possibly be secondary to that caused by the scab disease, since white ants frequently eat out scabby spots on potatoes. In the Tropics, however, otherwise sound potatoes are attacked by termites.

H. M. Russell found that sweet-potato tubers at Cutler, Fla., were being injured, the termites mining through the tuber and eating out nearly the entire interior. In most cases the insects entered the roots of the plants just below the earth and tunneled the stems. It is possible that termites similarly injure other tubers, as radishes, although there are no definite records. At Sabinal, Tex., on May 29, 1910, F. C. Pratt exposed a small colony of termites[2] in the ground while digging radishes.

CORN.

Injury by termites to corn has occasionally been recorded, as may be noted from the following field records of F. M. Webster, late in charge of Cereal and Forage Insect Investigations. G. G. Ainslie states that at Clemson College, S. C., on August 5, 1908, several dead stalks of corn were found in a cornfield: they proved to be hollowed out inside and

[1] Marlatt, C. L. The White Ant. U. S. Dept. Agr. Bur. Ent. Circ. 2d ser. no. 50, rev. ed., 8 p., 4 fig., January, 1908.

[2] *Eutermes* sp.; colonies commonly are found in the earth in the Southwest.

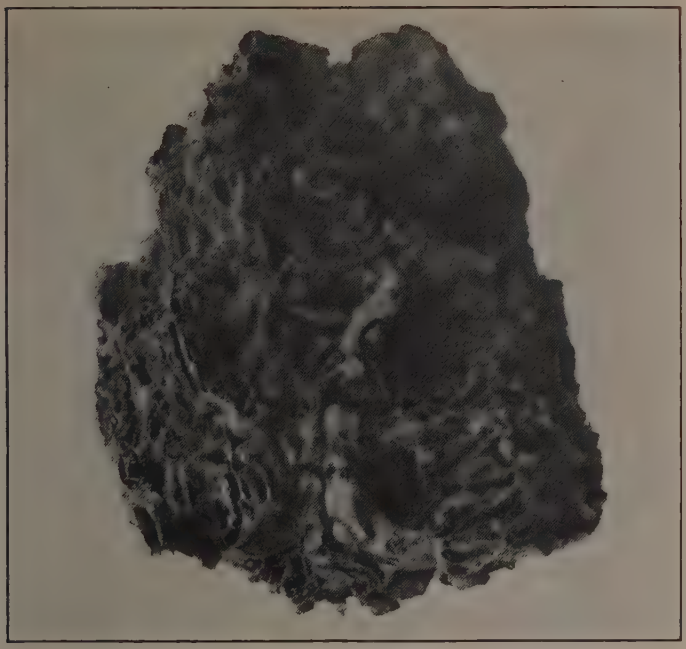


FIG. 1.—Heartwood of living chestnut tree disintegrated by *Leucotermes* sp. Falls Church, Va. (Original.)

FIG. 2.—Small corn plants with the "bud" killed by termites. These insects cut a hole into the stem at the base, severing the central shoot, which is dead at the top. Hurricane Mills, Tenn., June 19, 1912. Photograph by G. G. Ainslie. (Original.)

FIG. 1.—Cotton roots injured by termites. Granbury, Tex., June 30, 1910. Photograph by H. Pinkus. (Original.)

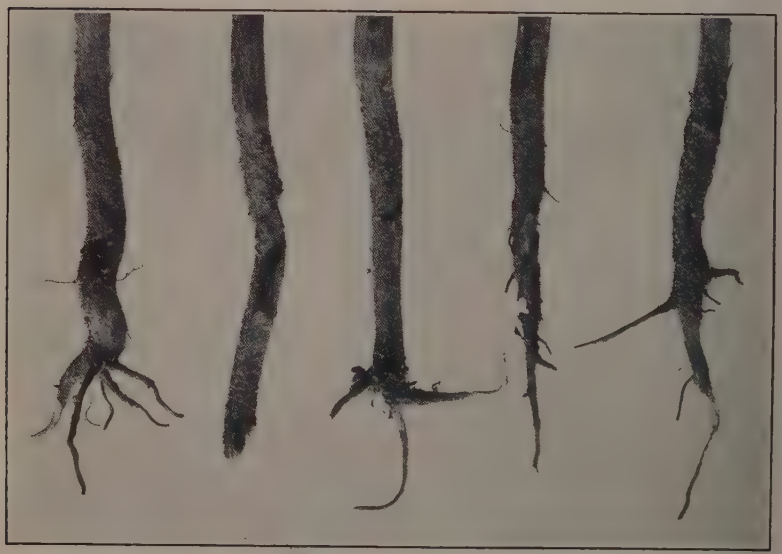


FIG. 2.—Cotton roots affected by root-rot and attacked by termites. Plano, Tex., July 12, 1910. Photograph by E. S. Tucker. (Original.)

DAMAGE TO COTTON PLANTS BY TERMITES.

full of white ants.[1] In every case, however, the stalk showed that it had been attacked first by the larger corn stalk-borer (*Diatræa saccharalis* Fab.) and drilled about the base. It could not be determined whether the plant was dead when the white ants attacked it or whether they killed it. The stalk was drilled out and hollowed up to about 10 inches from the ground. The plants when killed were about 2 feet high. On October 30 Ainslie again found many stalks of corn full of white ants. The stalks which contain the termites can be ascertained as soon as touched. In most cases the entire inside has been eaten out, leaving a thin shell with a plug of untouched pith at the top. The stalk was usually entered at the bottom, underground. No forms but workers could be found. About 5 per cent of the stalks were infested, and each one contained from 5 to 75 workers.

Ainslie states that at Hurricane Mills, Tenn., June 19, 1912, in a field of young corn, numerous plants were found with these insects[1] mining in the ground and even up into the stalks. In most cases there was evidence to show that the termites had been attracted by some previous work of another insect and had merely kept on and enlarged the holes already started. These plants, by their dwarfed and deformed appearance, usually indicated the nature of the previous work. However, some plants were found which had been injured solely by these white ants. The plants were healthy and normal except for a wilting of the central leaf or two. The termites had cut smoothly elliptical holes into the stalk just below the surface of the ground, but these holes were too far above the roots to be those of any kind of "budworm." Within the holes the termites had excavated upward, taking the central core cleanly out, so that the amputated leaves would almost fall out in the wind. The colonies were not large, and it may be that the insects worked through passages from one central nest. This ground had been cleared many years and there were then no stumps or other rubbish in the field. (Pl. IX, fig. 2, shows the manner of injury.)

Similar injury to the stalk and taproot of corn has been recorded by several others in the field in North Carolina, Tennessee, and Alabama, the injury sometimes being primary, all castes being found in the stalks, and the insects apparently making permanent habitations in the plants. Termites breed in the stubble in the autumn, winter, and early spring, and later sometimes attack the young plants or the seed.

In Kansas E. O. G. Kelly made observations indicating similar injury to corn in the field. At Wellington, Kans., on August 8, 1910, he states that several colonies of termites[2] were burrowing in cornstalks. Some of the stalks had been bored for three to four joints,

[1] *Leucotermes flavipes.* [2] *Leucotermes* sp. (probably *lucifugus*).

and the joints were simply shells. The tops of the plants attacked were dying. The termites seemed to prefer the pith. Some of the colonies were quite large and had attacked two or three stalks in one hill. On the 12th of August termites were active in five different cornfields. They had not attacked many plants in any area, but had severely bored those that were attacked, great hollows having been made by them. Some of the injured stalks had been previously attacked by *Sphenophorus maidis* Chittn., or other insects, but not all of them. The insects seemed to enter at a scar or break about the roots; none were above the ground. On the 22d of August Kelly found that quite a number of corn plants had been attacked by these insects and that the stalks were mere shells, having had the pith removed. No serious injury appeared to have been done to the plants, because most of them were small. By September 6 the corn plants were getting quite dry and the termites seemed to be increasing. In a cornfield on one farm there were numbers of attacked plants. This field was an old prairie field and had been planted to corn the year before. There were no decaying stumps or wood of any kind in the field, and the termites evidently subsisted on the cultivated crop. On October 14, 1910, the termites were still active, burrowing in the dry cornstalks. A colony dug out contained thousands. The ground was filled with their burrows. Their nest did not seem to be anything but a series of burrows with young larvæ, etc., here and there all through them. On November 26 the termites were still burrowing in the stalks. On February 15, 1911, with the temperature at 75° F. and the ground quite warm at noon, there was a swarm in a cornfield, along roadsides, and even from sidewalks in the city limits. On May 9 many termites were found in a cornfield that was planted to corn the year before; nine young plants had been injured. Single dead stalks sometimes contained 32 termites.

Similar damage to a living corn plant about 1 foot high, tunneled by white ants and not previously injured, was found by J. J. Davis on June 18, 1915, at West La Fayette, Ind.

H. E. Smith states that on May 8, 1913, in a field of corn 1½ miles northwest of Mulvane, Kans., he found that this species[1] had eaten all the seed before germination in about 6 feet in the row, and they were apparently working straight down the row. No others could be found in the field.

DAMAGE TO NURSERY STOCK, YOUNG PLANTATION STOCK, AND VINEYARDS.

There are numerous records of termite injury to young fruit and nut-tree seedlings in nurseries, to other nursery stock, and to young trees planted in recently cleared ground or soil rich in humus. The

[1] *Leucotermes* sp. (probably *lucifugus*).

injury, however, has been only occasional and not extensive, and usually has not been considered serious. The stock is usually attacked at a scar, where the roots have been injured or cut off, or at a graft, as "cleft-graft" apple stock.

APPLE.

At Wellington, Kans., on November 14, 1910, E. O. G. Kelly states that on several occasions dying and dead apple sprouts in a nursery had been severely burrowed. An examination of 3-year-old stock showed that the roots and body of a number of the trees had been burrowed in the same manner as the sprouts, and the termites[1] were in the burrows in these larger trees. About 5 per cent of the stand would have to be discarded on account of their ravages. The pest had been injurious for a number of years and was worse in dry years than in wet. The 3-year-old trees were quite badly damaged when they were put out in 1909, because the early spring was so dry. The 2-year-old trees were not very badly infested during the fall of 1910. Quite a number of young sprouts were girdled, and the result of girdling is a dead tree. A count in three rows of the 2-year-old stock gave results of 8, 7, and 12 per cent, or an average of 9 sprouts out of every 100, infested. In the spring or 1-year-old stock the infestation was quite severe. The rows near the hedge fence were 15 to 30 per cent infested; out farther, from 6 to 70 per cent were infested. The severe infestation ran in local spots, not being general over the field, but there were infested plants in all parts of the field (Pl. XI). An adjoining cornfield was badly infested, numbers of stalks being bored by them. Some of the trees were full of the insects, while some had been abandoned. On November 26 the termites were still active and burrowing in the apple sprouts. Peach sprouts and shade-tree sprouts in the same nursery were injured.

PECAN.

Herrick states that in Mississippi, in a pecan nursery where there was damage by termites, injury was most prevalent to seedling pecans of the 1-year growth.

A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, states that numerous reports relative to injury to pecan nursery trees by white ants have come from various parts of the pecan-growing area, as Texas, Florida, Mississippi (Pl. XII), Louisiana, etc. W. B. Wood investigated a case of serious infestation of a pecan nursery in the neighborhood of Petersburg, Va. An inspection, on October 8, 1912, of this nursery, which consisted largely of pecan trees varying in age from 1 to 4 years, showed that the severest injury to the

[1] *Leucotermes* sp. (probably *lucifugus*).

trees occurred on stock 1 and 2 years old. Trees that had reached an age of 3 years showed little injury. This difference was probably due to the fact that the trees 1 and 2 years old were planted on recently cleared woodland, whereas the old trees were on old land, though closely adjacent to the badly infested area. Of the trees 1 and 2 years old probably one-fourth of the total number had been destroyed during the summer, the injury being almost entirely below ground, although the excavations made by the termites occasionally extended an inch or two above the surface of the soil inside of the tree. Below ground the trees were frequently hollowed out until little more than a shell of bark remained. The insects made their entrance to the trees at some point below ground, the place most frequently chosen being the point where the taproot had been cut to cause it to branch out into a larger root system. From this point of entrance the insects worked upward, extending their galleries through the wood and enlarging them until the heart of the tree at the crown was entirely eaten away. Usually the affected trees did not show any indication of injury until they were badly damaged and then they died very quickly, the leaves sometimes drying on the limbs within a period of three or four days.

VINEYARDS.

Injury by termites to vineyards has occasionally been recorded in Algeria,[1] in Bordeaux, France, and in North America. Usually only the weak or old vines with many pruning scars are attacked, or dead or injured parts, or ramifications of the stem or branches invaded by other pests, the healthy ramifications of the stock being exempt from invasion. Signs of attack are sickly foliage or abortive buds, or the injury is observed at the time of cutting down to stock or making graftings. S. H. Scudder records fatal injury to the roots of grapevines in forcing houses at Salem, Mass.

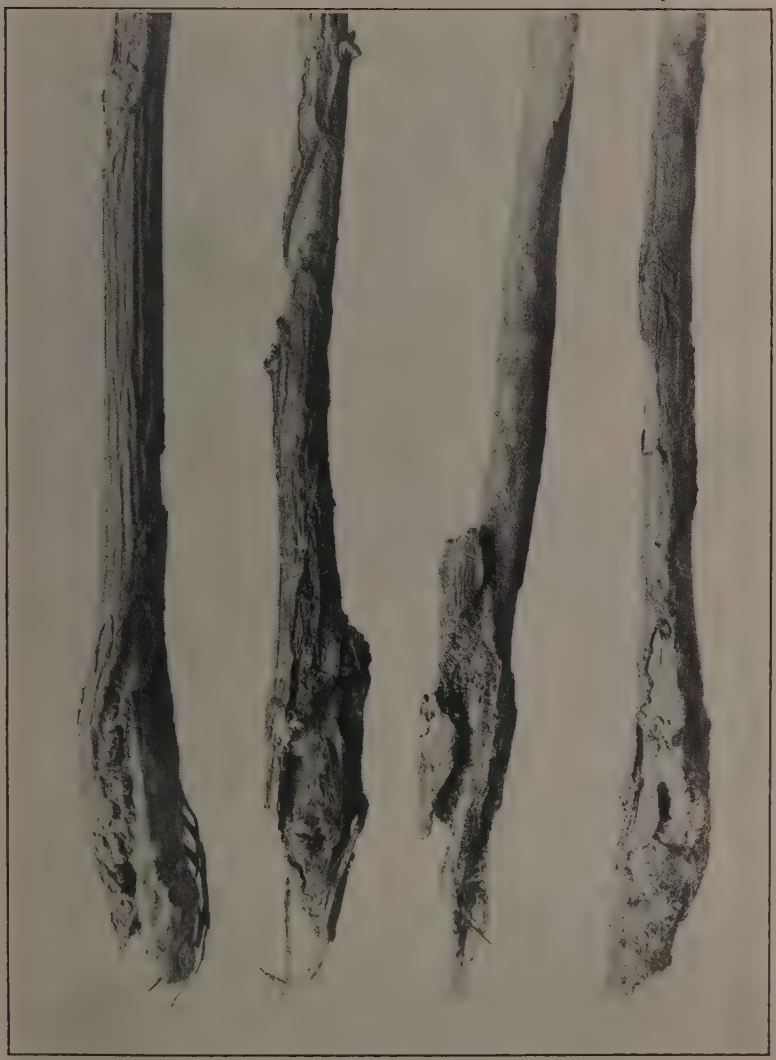
DAMAGE TO SHRUBS, FLOWERS, AND GREENHOUSE STOCK.

GREENHOUSE STOCK.

Termites injure a variety of shrubs, flowers in gardens as well as in greenhouses, and weeds. Hagen states that our common native termite,[2] introduced into Europe, so nearly destroyed one of the largest of the beautiful hothouses at Schoenbrun belonging to the Emperor of Austria that it had to be torn down. Besides the beams, the termites destroyed the tubs in which the plants were set. Hagen states in 1876 that a few years before he had observed termites swarming in clouds in the Botanical Garden at Cambridge, Mass. Manured

[1] By *Calotermes flavicollis* Fab.

[2] *Leucotermes flavipes.*

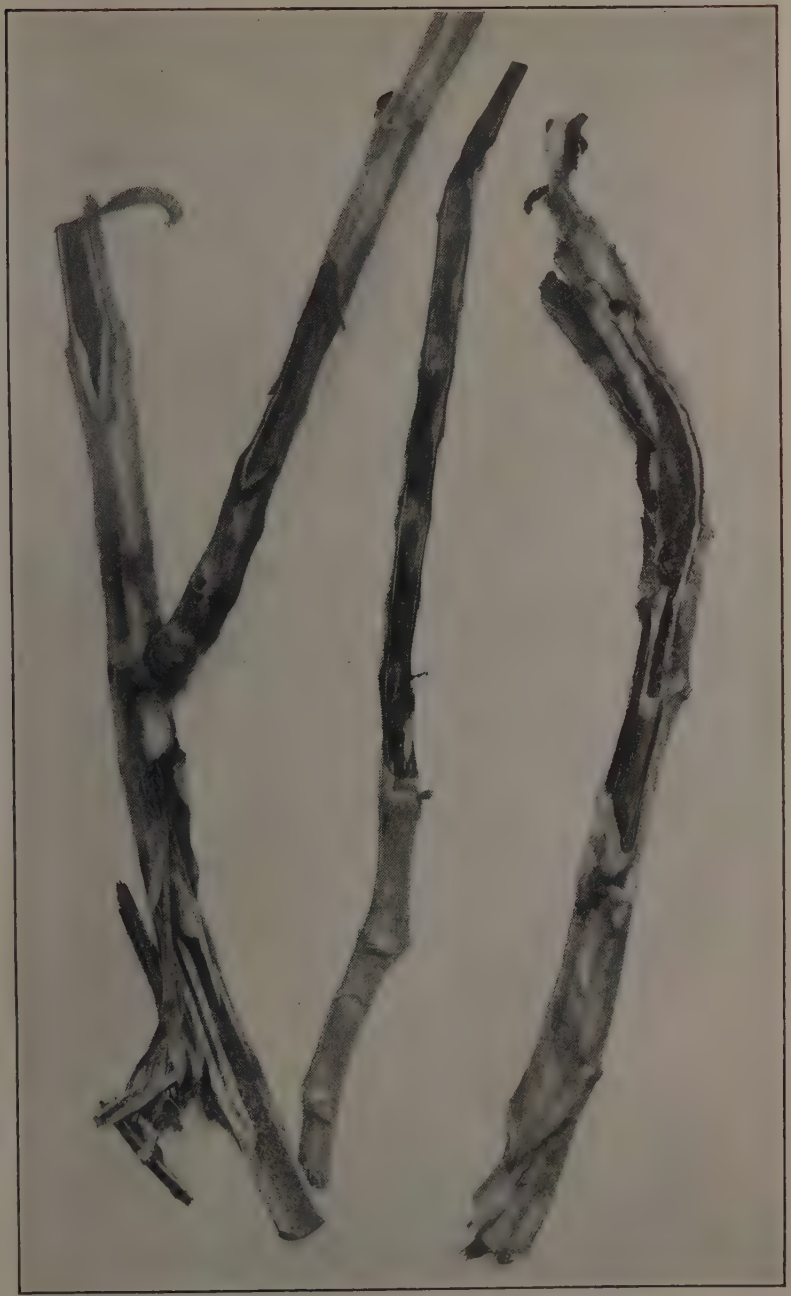


TERMITE DAMAGE TO NURSERY STOCK.

Damage to apple seedlings by *Leucotermes* sp. at Wellington, Kans. November, 1910. Photograph by E. O. G. Kelly. (Original.)

TERMITE DAMAGE TO NURSERY STOCK.

Pecan nursery stock killed by *Leucotermes flavipes*. Wortham, Miss., July 14, 1913. Photograph by J. H. Paine. (Original.)



TERMITE DAMAGE TO GARDEN PLANTS.

Geranium stems burrowed by "white ants." Damage extensive in lath house and garden at Brownsville, Tex., 1915. Photograph by C. H. Popenoe. (Original.)

flower beds around the walls of wooden buildings are a source of infestation by termites. The soil in such beds is always less compact and warmer, and termites have been observed by Hagen swarming from such beds.

Webster states[1] that in 1896 termites were destructive in Ohio, burrowing in the roots of small trees. He figures the injuries to geranium cuttings that were being propagated in a greenhouse near Cincinnati, the termites destroying many cuttings by eating them off the benches.

Chittenden states that the common white ant (*flavipes*) was recorded some years ago as occurring quite commonly on plants grown under glass, and that it is directly injurious to such growing vegetation as greenhouse geranium (Pl. XIII), chrysanthemum cuttings, and other herbaceous plants, especially those with large stems or more or less woody stalks. The stalks found to be injured had been tunneled through and through by the white ants, and at the bottom near the roots the plants had given way to the inroads of numerous individuals. Several plants were killed outright. The causes of such attack can easily be traced to the colonies in old sticks that are used for recording the date of setting out, etc., and the termites mining in wooden benches. One such case was reported by L. C. Corbett, of the Bureau of Plant Industry, who stated that large begonia plants at Morgantown, W. Va., had been injured in a similar manner. Infestation was due to the undermining of the bench structure beneath the plants, the insects having burrowed through the wood up through the drainage holes in the bottoms of the pots. Florists are sometimes sorely tried by these insects and state that "they attack everything." Roses grown in greenhouses are sometimes badly injured by the girdling of the white ants. While partial to geraniums and chrysanthemums, termites, as shown by the records of the Bureau of Entomology, injure jasmine, pansies, and oleander. Wooden benches and plant pots are infested, as well as the woodwork of the buildings, the insects coming up through the ground from outside colonies. Termites may be considered a serious greenhouse pest. According to G. A. Dean, entomologist of the Kansas State Agricultural College, on January 29, 1915, termites[2] swarmed in a greenhouse; there was a swarm in the same greenhouse on December 26, 1914. W. E. Britton states[3] that more than 200 geranium plants had been ruined by termites,[4] which tunneled out the inside of the stem and main roots in the field at New Rochelle, N. Y.

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[1] Webster, F. M. Some Particularly Destructive Insects of Ohio. Ohio Agr. Expt. Sta. Bul. 68, p. 19–58, 6 pls., 1896.

[2] *Leucotermes lucifugus.*

[3] Britton, W. E. Injury to Geraniums by White Ants. *In* 14th Rpt. Connecticut State Ent. f. 1914 (Conn. Agr. Expt. Sta. Rpt. f. 1914, pt. 3), p. 196–197, 1915.

[4] *Leucotermes* sp.

ORNAMENTAL PLANTS.

F. C. Pratt states that at Sabinal, Tex., on July 11, 1910, some small pieces of Opuntia infested with Mimorista larvæ were entirely covered with soil galleries by termites. Many insects were found. It was also noticed that the galleries were extended to the healthy plants. Most of the small pieces were shriveled, but this condition was primarily due to the termite attack. This injury to ornamental cacti has occurred many times before.

On August 24, 1915, at Jacumba, Cal., F. P. Keen found workers and soldiers of *Hamitermes* sp. feeding on the surface of the rind of Yucca, where protected by the leaf bases, which are closely appressed to the stalk. The insects worked between the rosette of leaves and the flower stem. Jacumba is near the International Boundary Line and in a desert region.

At Washington, D. C., termites (*L. flavipes*) constructed earthlike tunnels around a wooden fern box in a window of a school building in October, 1915. When the insects came to a hole in one corner of the box—bored to allow the excess water to drip away—they suspended hanging tubes down through this hole. These were about 3 inches in length and 1½ inches in width at the bottom—the widest point. The opening at the bottom, through which the antennæ of the workers and soldiers could be seen projecting, was about ¼ inch in diameter. The shape of these tubes was somewhat like a funnel but the flare was not quite so marked. Termites infest the roots and stems of ornamental plants, in gardens or potted.

WEEDS.

E. S. Tucker states that on July 30, 1909, at Dallas, Tex., termites[1] occupied the hollow roots of a weed, *Leptilon canadense*. The insects had effected entrance through a hole in the root. On September 29, 1911, at Wellington, Kans., according to E. O. G. Kelly, termites had attacked stems of cocklebur, utilizing the entrance hole made by *Papaipema nitela* Hbn. At Colorado Springs, Colo., on March 7, 1915, at an elevation of 6,100 feet, live termites[1] were noted by G. Hofer in the dead stem of the common thistle.

PREVENTIVE AND REMEDIAL MEASURES.

PREVENTIVES.

PROTECTION OF WOODWORK IN BUILDINGS.

The fact that the beams, as "joists," "studding," "stringers," etc., of the basement are embedded in concrete is only a partial protection. In the settling of the house concrete is almost sure

[1] *Leucotermes* sp.

to crack, allowing avenues of ingress, and the beams and joists put down in the moist material soon partially decay and become exceptionally good breeding places. From such beams the white ants carry their burrows up through the timbers of the first and even second floors (Marlatt). Flooring commonly becomes infested through the wooden beams or stringers laid directly on the earth or in moist concrete; untreated beams should never be laid on the earth and the spaces filled in with concrete, or in moist concrete, since they will rot, even if they do not become infested. An air space should intervene. Therefore the foundations of buildings should be entirely of brick, stone, or concrete, including the basement floor, without beams or joists sunken in the ground or concrete, and especially should this method of construction be followed in tropical and subtropical regions. H. von Schrenk, of St. Louis, Mo., states that in no case should timber joists be completely surrounded with mortar or brick; there should be an air space completely around the joists so as to permit air circulation.

Marlatt states that complete dryness is an important means of rendering buildings safe from attack. Books and valuable documents, etc., should not be packed away in unventilated chambers where they may become moist and moldy, as they are then particularly subject to attack by white ants, which are very likely to be present in old buildings, even though their work has not been sufficient to bring them into special notice.

USE OF RESISTANT WOODS.

Certain species of woods are highly resistant to termite attack, due to the presence of oils, alkaloids, gums, or resins as well as to hardness and other factors.

Maj. George Ahern, United States Army, reports, according to Marlatt, that California redwood has been used for more than 25 years in the Philippines and has never been known to be injured by white ants. Its use in Manila is very general, especially in the construction of cabinets, filing cases, etc., where it is desirable to protect valuable papers from these insects. Redwood is not resistant against termite attack in contact with the ground in California.

Another resistant North American cabinet wood is black walnut; of the tropical species, teak, mahogany, and "peroba" are resistant woods.

As to timber to be set in contact with the ground, E. Gerry gives data[1] on the durability of native hardwoods; of the conifers, incense cedar, eastern red cedar or juniper, western red cedar, and southern bald cypress are resistant. Durable and resistant exotic structural

[1] Gerry, Eloise. Tyloses: Their occurrence and practical significance in some American woods. *In* Jour. Agr. Res., v. 1, no. 6, p. 445–470 (p. 463–464), pl. 52–59, Mar. 25, 1914.

timbers are teak, greenheart, lignum-vitæ, etc. "Karri" (*Eucalyptus diversicolor*) and "jarrah" (*E. marginata*), of Australia, are resistant although not immune to attack by termites.

REMEDIES.

LOCATION OF DAMAGE TO WOODWORK IN BUILDINGS.

The point of emergence of the flying termites may indicate approximately the location of the infested timbers; if the insects are not observed swarming, large numbers of the dead winged adults or the discarded wings will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidence. In efforts to stop further damage by termites in buildings it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside central colony. The destruction of the winged, colonizing adults at the time of the emergence, while advisable in preventing the establishment of potential new colonies, is of no value in eradicating the insects infesting the woodwork.

Another indication of infestation is the presence of longitudinal earthlike tubes, of small diameter, constructed on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material from the ground to the woodwork. Drenching the ground—where these tubes originate—with kerosene oil will afford relief. A prompt examination of the foundation timbers, such as beams and joists in contact with the ground, should be made to determine the approximate point of entrance of the insects and the extent of the damage already accomplished. It may be necessary to tear up the flooring and other woodwork to accomplish this. The foundation timbers and interior woodwork found damaged should be removed and burned and the ground where they were set drenched with kerosene oil.

ROCK FOUNDATIONS AND WOOD PRESERVATIVES.

The main point is to prevent the insects from gaining access to the woodwork from colonies in the ground, either by means of substituting rock or concrete foundations and concrete or tile flooring in the basement or by protecting the foundation timbers in contact with the ground by impregnation of the wood with coal-tar creosote.

It is very rarely possible to find and destroy the external colony, and it may be necessary to replace the foundation of the buildings with walls and floorings of stone, concrete, or other form of rock composition, and this is the most permanent and complete preventive. In the case of the National Museum buildings, the Carnegie Institution of Washington, and several private edifices in Washington,

FIG. 1.—Injury by "white ants" to yellow-pine pole impregnated with 12 pounds of coal-tar creosote per cubic foot in a telephone line set along Gulf coast near Pass Christian, Miss., since 1899. Average penetration of the preservative, 1¼ inches; surface intact; insects entered through deep season checks; damage more extensive above ground line. Shell of outer layers of wood broken away to show eaten-out interior. Photograph by American Telephone and Telegraph Co. (Original.)

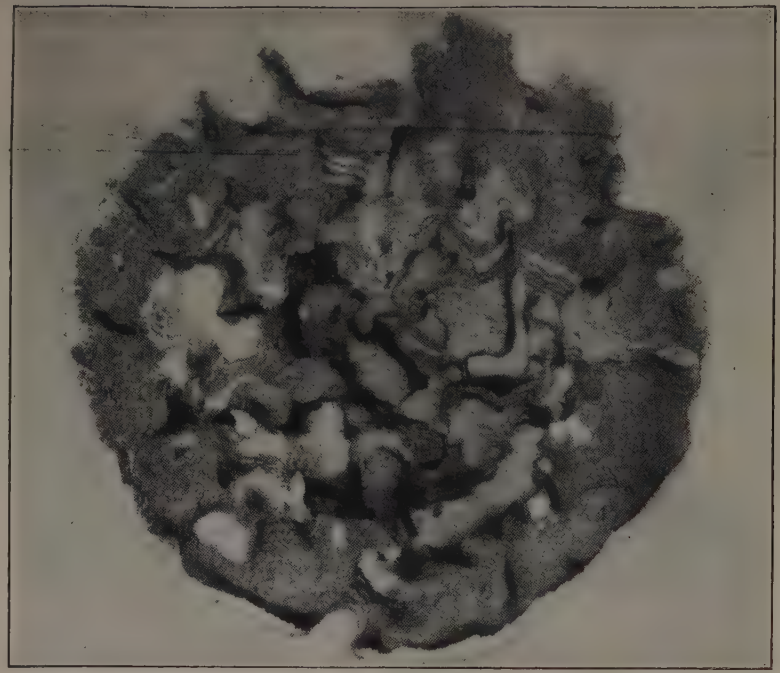

FIG. 2.—Layers of bandage muslin lying on wooden floor of a hospital in Philadelphia, Pa., destroyed by termites. Photograph by C. H. Popenoe. (Original.)

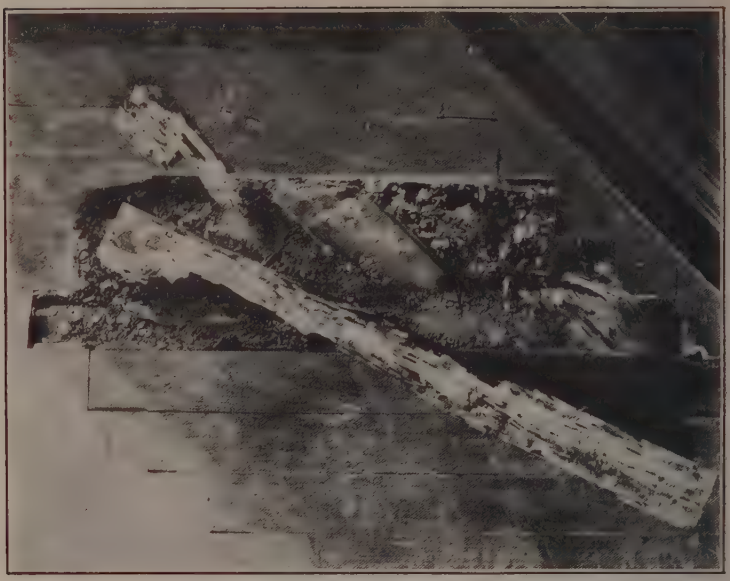

FIG. 1.—Oak floor honeycombed by *Leucotermes flavipes*. Washington, D. C., July, 1915. Photograph by C. H. Popenoe. (Original.)

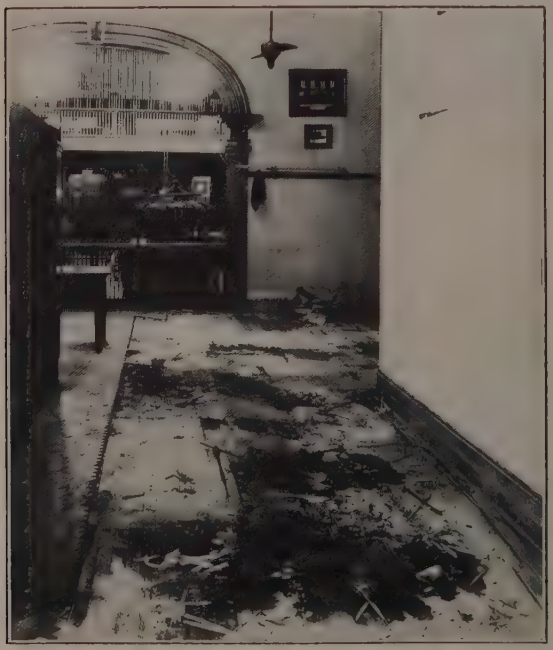

FIG. 2.—Pine subfloor underneath the oak floor shown in figure 1. Photograph by C. H. Popenoe. (Original.)

D. C., this course was finally adopted, with the result that white ants were completely excluded and their work terminated (Marlatt). This measure was also necessary in the case of the buildings of the State Agricultural College at Manhattan, Kans., where wooden partitions, floors, and other woodwork were torn out and cement floors and walls substituted.

If the foundation of the building is such that damage to the woodwork is extensive and likely to recur, and it is impracticable to replace with concrete or stone, it is advisable to replace the exposed interior woodwork with wood impregnated by a 6 per cent solution of zinc chlorid or a 1 per cent solution of bichlorid of mercury; except in case of flooring in contact with the ground or in wet situations, where such preservatives would leach out.

In case of greenhouses iron frames and concrete work should, wherever possible, replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

In some cases thorough and repeated drenching of infested timbers, where accessible, with kerosene oil may afford temporary relief and kill some of the white ants. Kerosene oil should be poured into the crevices through which the winged insects emerge from infested wood. As the insects may have entered the house through soil channels by means of pillars or the supports of porchings and steps, these last should be removed if damaged and the ground soaked with kerosene.

OTHER TIMBER IN CONTACT WITH THE GROUND.

Poles,[1] mine props,[2] railroad ties, posts, construction timber, and other wood in contact with the ground should, since these insects attack all classes of wood to which they can attain access from the ground, be treated with chemical preservatives to render them more resistant to termite attack. Superficial methods, temporarily prolonging the length of service of timber, include brush and dipping methods of treatment. From experiments it has been determined that for timber in contact with the ground brush and dipping treatments with coal-tar creosote will render southern yellow pine resistant for at least two to three years in the Southern States and effective for from three to four years and longer. Under the closed-cylinder pressure process ("full cell" treatment) of impregnation of southern yellow-pine timber with coal-tar creosote, at least 16 years' service is attained in

[1] Snyder, T. E. Insects Injurious to Forests and Forest Products. U. S. Dept. Agr. Bur. Ent. Bul. 94, pts. 1–2, 85 p., 16 pl., 14 fig., 1910–1915. Damage to Telephone and Telegraph Poles by Wood-boring Insects. U. S. Dept. Agr. Bur. Ent. Circ. 134, 6 p., 3 fig., Mar. 7, 1911.

[2] Snyder, T. E. Insect Damage to Mine Props and Methods of Preventing the Injury. U. S. Dept. Agr. Bur. Ent. Circ. 156, 4 p., July 13, 1912.

the Southern States[1] (Pl. XIV, fig. 1). After many years' service there may be a deterioration in the treated wood. Other chemical preservatives are in use, but coal-tar creosote is usually the most effective preventive since it is also a fungicide and will not leach out in wet situations. For permanent timbers to be used in coal mines a pressure process with zinc chlorid has been found more suitable, according to tests conducted by the Forest Service.

CABINET WOODS.

Impregnation of cabinet woods, furniture, etc., with chlorinated naphthalene[2] is effective in rendering wood more resistant to termite attack; treated, perishable, northern cabinet hardwoods comparing favorably with untreated teak and mahogany after two and one-half years' test.

WOOD-PULP PRODUCTS.

Treatments have been tested for wood-pulp products, such as the various wood-fiber, "processed," or "composition" boards used for interior finish and as substitutes for lath, etc., when they are to be used in the Tropics and portions of the southern United States to prevent attack by white ants. It has been found that the practical method is to add various poisons during the manufacture of these boards.

Experiments with such poisons and insecticides as white arsenic, bichlorid of mercury, zinc chlorid, copper sulphate, sodium fluorid, phenol, and dihydrogen potassium arsenate (KH_2AsO_4) have been conducted by manufacturers upon the recommendation of the Bureau of Entomology. It has been determined that where insoluble chemicals were added in the process of manufacture of the board there was so low a retention that the cost rendered the treatment commercially impossible. Also in the manufacture of the board a large amount of water is employed which it is not practicable to save, and consequently a large amount of chemical, whether soluble or insoluble, is carried away. As yet the results of these tests do not warrant the drawing of definite conclusions.

Dihydrogen potassium arsenate is a powerful insecticide,[3] is soluble in cold water, and should prove as effective as the insoluble white arsenic. Sodium fluorid has been been proved, by experiments of A. L. Quaintance, an effective insecticide and is also being tested as

[1] In the Tropics and along the Gulf coast of the United States, where seasonal checking of timber is liable to occur after treatment and setting, a penetration sufficient to prevent white ants from infesting the timber through these checks should be secured. A more uniform penetration with a practical minimum to allow for checking, and a heavier impregnation (at least 15 pounds per cubic foot) are necessary. The depth of penetration can be determined roughly by the thickness of the sapwood.

[2] Process devised by the Western Electric Co., of New York.

[3] Information on this insecticide was obtained from the Branch of Southern Field Crop Insect Investigations from the experiments of B. R. Coad.

a treatment to render timber more resistant to attack by insects. Wood soaked in a 2 per cent solution is under test.

STORED MATERIAL.

Injury to books, paper, documents, and other stored material or products is usually indirect, the insects as a rule burrowing through such material only where it is in contact with infested wood. Hence, since the source of infestation is decaying wood, if the insects can be kept out of wooden structures this damage can be prevented. When once the source (white ants coming up through the earth where there is moisture) is shut off, the insects infesting stored material soon die out or can be killed by spreading out infested books, documents, and other stored material or products to dry in the sun or in an oven. Later they can be restored to the repaired building or a safer place. Most damage of this sort can be prevented by the substitution of concrete foundations to buildings or by using timber impregnated with coal-tar creosote.

FUMIGATION.

Where the injury is confined to books and papers, other stored material, or exposed woodwork and furniture, hydrocyanic-acid gas fumigation can be attempted, exposing if possible also, by opening up floors, the infested joists beneath and spreading out the books and opening cases and wardrobes. As hydrocyanic-acid gas is poisonous and dangerous, fumigation should be attempted only by those with experience.[1]

LIVING TREES.

Owing to the subterranean habit of termites, it is extremely difficult to prevent or remedy injury to living forest, fruit, or shade trees. Care should be taken that the trees do not become scarred near the base, in order to prevent heart rot and subsequent infestation. Proper clean forest, orchard, and horticultural management is to be recommended. Properly executed tree surgery[2] sometimes may be effective in repairing damage to valuable old trees. Dead and dying infested trees should be removed and burned. Prunings should not be left lying on the ground, but should be burned.

NURSERY STOCK, FIELD CROPS, AND VINEYARDS.

Injury to nursery stock will be most serious on recently cleared land where there is abundant decaying wood. Such débris, in which the insects breed, should be removed. In general, the use of recently

[1] For a description of the use of hydrocyanic-acid gas see Howard, L. O., and Popenoe, C. H., Hydrocyanic-acid Gas Against Household Insects, U. S. Dept. Agr., Farmers' Bul. 699.

[2] Collins, J. F. Practical Tree Surgery. *In* U. S. Dept. Agr. Yearbook for 1913, p. 163–190, pl. 16–22, 1913.

cleared land should be avoided in planting nursery stock. In case of nursery stock, Herrick recommends the growing of two or three cereal crops on newly cleared land before setting out pecan stock, and suggests experiments with commercial fertilizers. Experiments with commercial fertilizers and chemical compounds to determine whether they will serve as preventives are to be conducted by the Bureau of Entomology.

Sometimes injury by termites to corn in Kansas, according to Marlatt, is due to the method of plowing under old stubble, in which the insects breed. This practice should be discontinued if there is serious damage by white ants. Allowing the land to lie fallow for one year before planting should be of value; the same can be said of deep fall plowing. The practice of better farming methods, with rotation of crops, will prevent damage to field crops.

In case of vineyards care should be taken in pruning operations to reduce the surfaces cicatrized; all dead or diseased vines should be removed. Cuts should be painted over with coal tar. The various mastics employed in grafting may prove to be effective preventives. Prunings should not be left lying on the ground, but should be burned.

FLOWERS AND GREENHOUSE STOCK.

In case of flower or truck gardens, especially where near the woodwork of buildings, less animal manure should be used, in order to protect not only the building but also the plants.

In greenhouses the removal of decayed infested wood will prevent the plants from becoming infested in turn. Iron frames and concrete work should wherever possible replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

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